FEDERAL EXPERIMENT STATION IN PUERTO RICO

of the

UNITED STATES DEPARTMENT OF AGRICULTURE

MAYAGUEZ, PUERTO RICO

BULLETIN No. 44

BIOLOGY OF THE BAMBOO POWDER-POST BEETLE IN PUERTO RICO

By

HAROLD K. PLANK, *Entomologist*

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CONTENTS

INTRODUCTION

Of the few insects that attack harvested bamboo, the most serious in Puerto Rico is a small wood-boring beetle, *Dinoderus minutus* (F.), commonly called the bamboo powder-post beetle ("escarabajo del bambú seco").[1] Always troublesome wherever bamboo is stored, it frequently becomes so abundant as to destroy or seriously damage great quantities of this increasingly useful wood. The beetle also attacks a large number of other vegetable products, particularly under conditions of undisturbed storage. From its tunnels it characteristically discharges much light finely powdered material which accumulates beneath or alongside the objects infested. For this reason, in Puerto Rico it has often, though erroneously and confusingly, been called "polilla," a well-established local common name applied to the power-post or dry-wood termites, *Kalotermes* (*Cryptotermes*) spp., which have a slightly similar habit.

[1] Order Coleoptera, family Bostrichidae. Determined by W. S. Fisher, Bureau of Entomology and Plant Quarantine.

Although not a termite, *Dinoderus minutus* belongs to a family of beetles which usually live in wood and are notorious for their boring habits. One member of this family *Scobicia declivis* (Lec.) (the lead-cable borer), is capable of penetrating even lead or the lead alloy used as cable sheathing (2, p. 41).[2] However, not all the products in which these beetles are found would serve as breeding media or even as food materials, and much of the damage done to those that are unsuitable may be considered as incidental to the general habit of the group. It is this incidental damage, almost as much as the feeding of the larvae, that makes *D. minutus* extremely important economically. Although it may not actively reproduce in some species of bamboo, no species has yet been tested in Puerto Rico that it will not enter. In more susceptible species the borings of the adults are extensive, and these borings, with the subsequent mining by the larvae, either greatly mar the appearance of the wood and weaken it for all important uses, or ultimately reduce it to a mass of powder and fibers (figs. 1, 2, and 3).

This bulletin records studies made of the biology and habits of the beetle as a basis for control measures.

DISTRIBUTION AND PRODUCTS ATTACKED

Dinoderus minutus is a common cosmopolitan species of the tropical regions of the world. Besides being present in Puerto Rico, it has been recorded as occurring in Brazil, China, the Netherlands East Indies, Guadeloupe, Hawaii, India, Japan, Java, Malaya, Mauritius, Philippine Islands, Réunion, Siam, Straits Settlements, Tahiti, and Florida and Louisiana in the United States.[3] Its presence in Sumatra and Zanzibar is mentioned by Miller (*7, p. 22*), and in Natal, Union of South Africa, by Tooke and Scott (*12, p. 7*). Bruner, Scaramuzza, and Otero (*1, pp. 18, 189*) list this insect as a pest in Cuba of bamboo ("only dry culms") and of the mature kernels of corn. The writer has also seen evidence of its infestation in dry bamboo at Savannah, Ga., and at numerous places in Ecuador.

Besides the dry wood of various species and varieties of bamboo, the following plants and plant products are known to be attacked: *Arundo donax L.* ("caña de Castilla" or "guajana"), *Calamus* sp. (rattan), *Castanea* sp. (chestnut), *Derris* sp. roots, *Dioscorea* sp. (yam), *Gynerium sagittatum* (Aubl.) Beauv. ("caña de India" or "cana brava"), *G. saccharoides*, *Ipomoea batatus* (L.) Lam. (sweet-potato), *Oryza sativa* L. (rice), *Saccharum officinarum* L. (sugarcane), lily bulbs, dried bananas, stored chocolate, wheat flour, stored corn, and cotton goods.[3] In addition to bamboo, flour, and sweet-corn seed, Wolcott (*13, p. 242*) records in Puerto Rico the "dead stem of *Cajan cajan* (L.) Millsp." ("gandul" or pigeonpea). The writer has found 4 percent of the kernels of the USDA–34 variety of sweet corn that had been kept on the cob in open storage for about a month to be infested by adults of this insect (*11, p. 22*). Miller (*7, p. 23*) reports damage to drying tobacco leaves, but considers such damage accidental.

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[2] Italic numbers in parentheses refer to Literature Cited, p. 29.

[3] Letter from Lee A. Strong, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, to L. C. McAlister, Jr., under date of December 27, 1935.

FIGURE 1.—Partition and shelving made of split culms of *Bambusa vulgaris* (the common bamboo) several months after installation. The wood has been so riddled by the powder-post beetle, *Dinoderus minutus*, as to be unserviceable. Note characteristic accumulation of finely powdered wood and excrement thrown out by the adults from their tunnels.

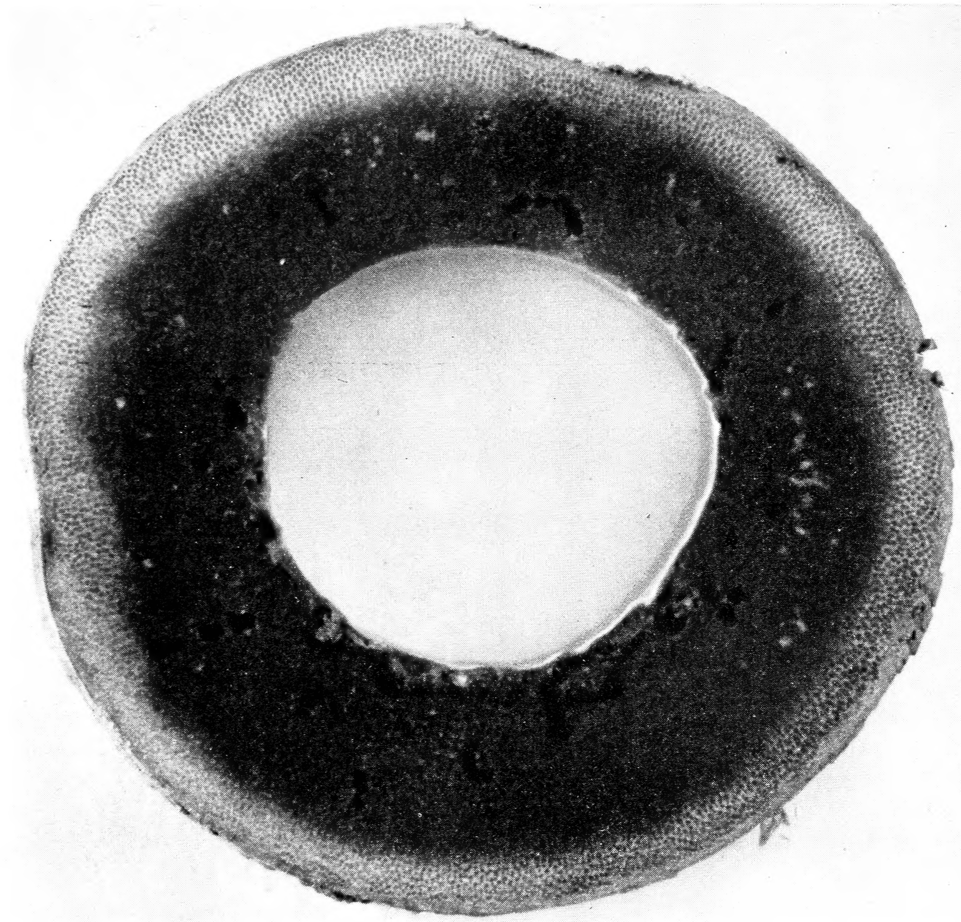

FIGURE 2.—Cross section of a basal internode of a 1-year-old culm of *Bambusa vulgaris*, showing the starch-bearing zone that comprises the inner three-fourths of the culm wall, dark area produced by an application of iodine solution over surface of entire section. Note holes in starchy wood only, the result of attack by adults and larvae of *Dinoderus minutus* during 3 months of exposure. The irregular, small, lighter areas in this zone are the exposed ends of larval mines packed with excrement, not stained by the iodine because composed of woody material from which the larvae had extracted the starch during ingestion. × 1.7.

LIFE HISTORY

Attack is begun by the adults, and in bamboo this often takes place within 24 hours after the culms have been cut and assembled for drying or storage. Dead or dying culms left in the clumps in the field have rarely been attacked, never those that are growing. Entrance is gained at the cut ends, the leaf-sheath scar about the nodes and buds, or wherever else there is sufficient break in the rind or contact with other objects to afford foothold and leverage. Once inside, the beetles extend their cylindrical burrows into the soft inner portion of the wall of hollow culms or into the central portion of solid culms, where (as shown in fig. 4) the fibrovascular bundles are widely spaced and ordinarily contain large vessels, and the intervening pithy tissue is most abundant. Usually this tissue is rich in starch and the more there is in

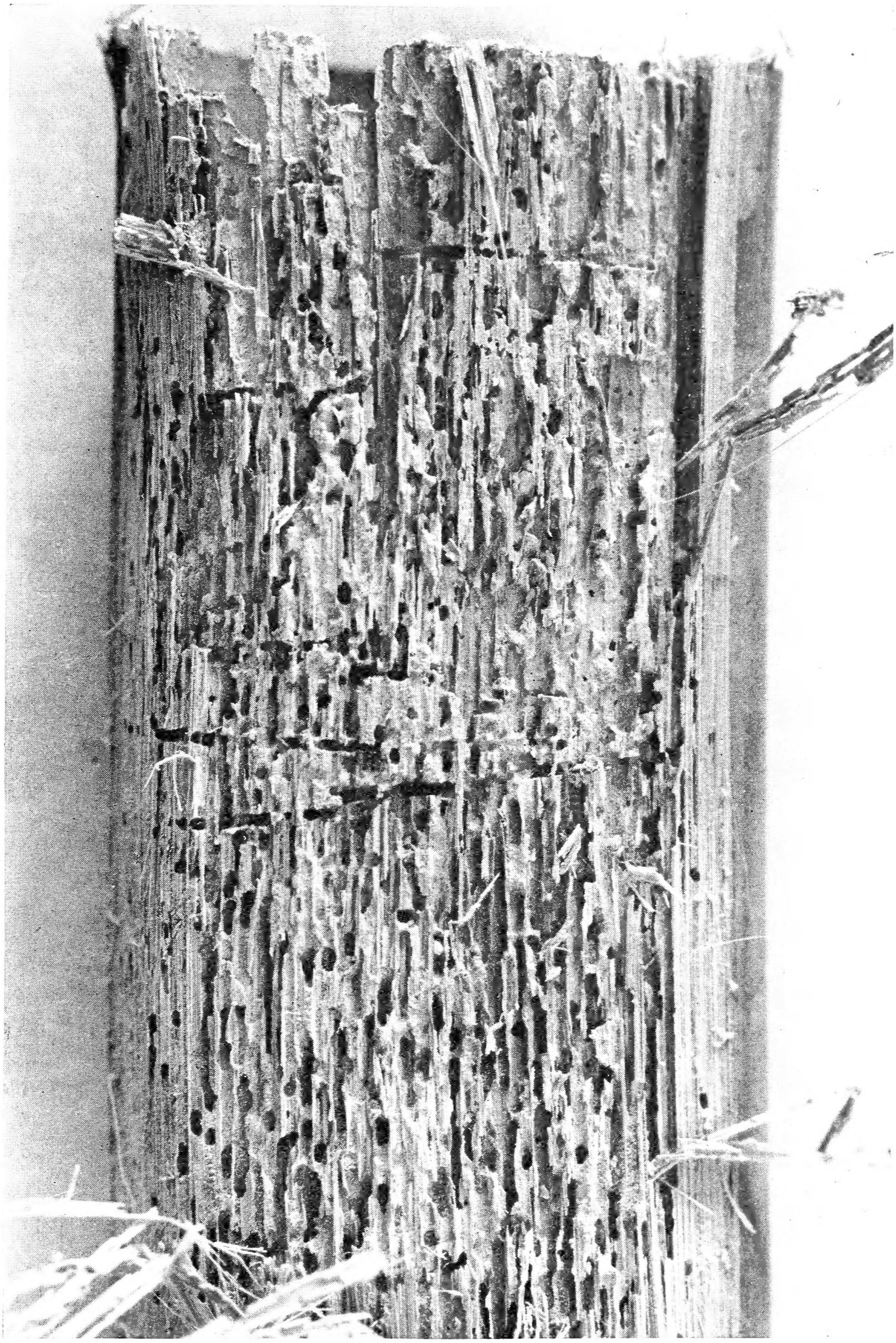

FIGURE 3.—Part of a middle internode of a 1-year-old culm of *Bambusa vulgaris* with the rind stripped off to show destruction of starchy interior by adults and larvae of *Dinoderus minutus* within 3 months after harvest. Note oviposition tunnels made across the grain by infesting adults and feeding mines parallel to the grain made by the larvae. Holes made at right angles to the surface, seen along the edges of the exposed area, were made by emerging adults. × 1.0.

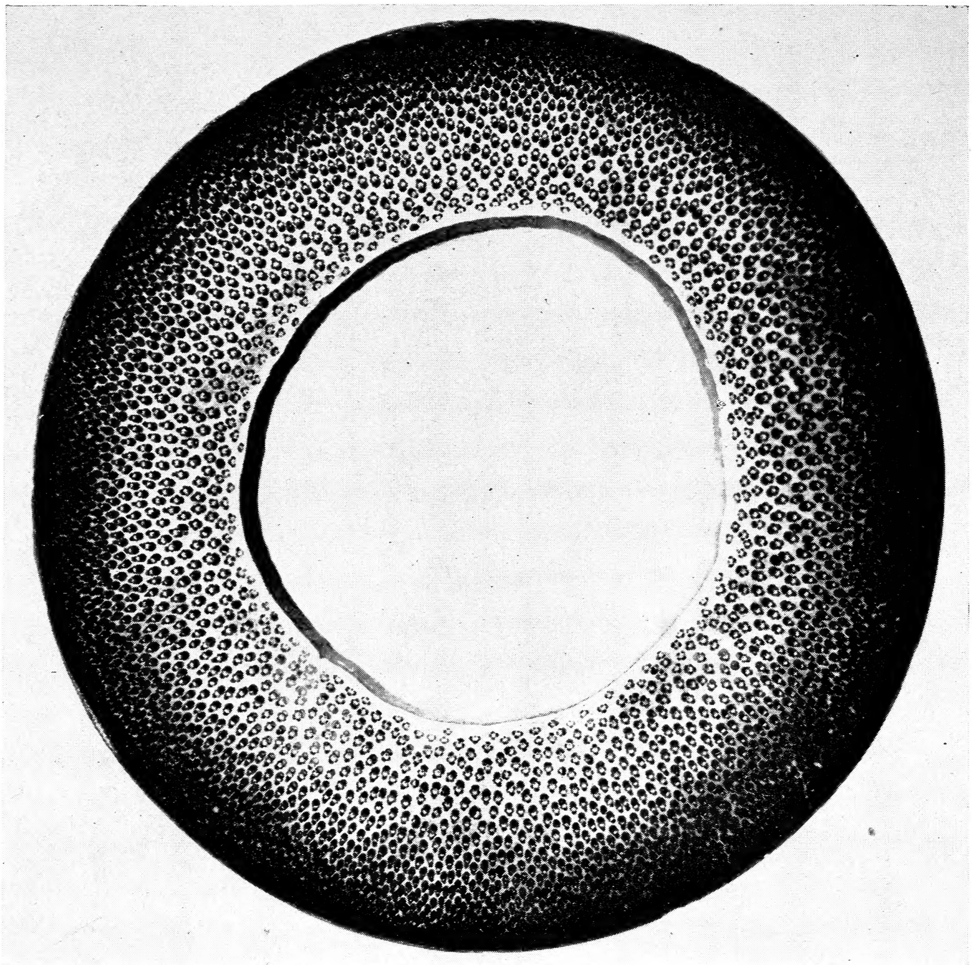

FIGURE 4.—Cross section of a basal internode of a 1-year-old culm of *Bambusa tulda* Munro polished to show arrangement of fibrovascular bundles which are farther apart and contain larger vessels in the inner than in the outer region of the culm wall. Note abundance of intervening pithy tissue in the inner region. In some species of bamboo this tissue is rich in starch, and the stronger the concentration of starch the heavier is the attack by *Dinoderus minutus*. × 1.5.

a piece of bamboo the heavier is the attack by this powder-post beetle. A typical example of the attractiveness of starchy wood is shown in figure 2. In some pieces, particularly of young wood having a uniform distribution of starch, the beetles destroyed everything but the hardest fibers and the rind.

The adults may make their entrance tunnels longitudinally, as from a cut end, or at right angles to the axis of the culm if entering from a break in the side, but after they reach pithy tissue they extend their tunnels around the interior of the culm at right angles to the grain of the wood. As they cut the fibrovascular bundles in this process the beetles deposit their eggs singly in the ends of the severed vessels, which they then close with woody excrement (*10, pp. 71–73*). These oviposition tunnels, about 1.3 mm. in diameter, are comparatively free of

powdered wood and are open to the outside, one or more adults passing back and forth in them at will. When the newly hatched larvae begin to feed they burrow into the pithy tissue parallel to the grain of the wood and pack the resulting powdery material behind them as they proceed. The two kinds of tunnels are well illustrated in figure 3.

On splitting open pieces of the common bamboo (*Bambusa vulgaris* Schrad.) which had been exposed to beetle attack for about 6 weeks and in which larval infestation was beginning to develop, larval tunnels were found to start from a point about ½ inch from the outside entrance of the oviposition tunnels. Farther inward the number and size of the larvae gradually decreased until only eggs were found. One of these eggs is shown in a vessel of a fibrovascular bundle in figure 5. The larger or more broadly rounded end of the egg was always inserted first, as shown in figure 6, and the other or narrower extremity was usually about 0.75 mm. below the tunnel end of the vessel. Since no eggs have been found in other locations, such as the exposed edges of a cross section or of a break in the rind, it is probable that this is the usual, if not the only, method of oviposition in bamboo.

FIGURE 5.—Piece of bamboo split longitudinally to show egg of *Dinoderus minutus* deposited in tubular vessel of wood from oviposition tunnel, segment of which is shown at top. Note end of vessel plugged with excrement from floor of tunnel. × 55.

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FIGURE 6.—Egg of *Dinoderus minutus* in vessel in bamboo wood. The usual plug of beetle excrement in end of vessel was removed in splitting the wood, and part of the semitransparent vessel lining was left over the egg. Note that the large end of egg was inserted first. × 55.

Egg

Because of their extreme fragility, only a few eggs could be extracted from bamboo wood without injury. To secure data on oviposition and also a supply of eggs for further biological study, other methods were tried.

By frequent observation of beetles taken from oviposition tunnels and caged with some of the powdery excrement from these tunnels, it was found that eggs were sometimes deposited loosely in this excrement. However, under these artificial conditions, the beetles soon died and the small number of eggs deposited seriously limited the practicability of this method for use in rearing work.

Since *Dinoderus minutus* is known to infest corn seed, dry kernels of the USDA–34 variety of sweet corn were tried as an oviposition medium. When caged in vials with several kernels partly split open, the adults began to feed almost immediately. The beetles seemed to

live normally in this medium and soon began to oviposit freely in the excrement resulting from boring and feeding. Each day the kernels of corn and the vials were cleaned with a soft brush, and the excrement was searched under the microscope for eggs. In this way it was possible to obtain intact eggs of known date of deposition for biological studies. These eggs did not vary greatly in shape or size from those found in bamboo. A series of eggs deposited under both conditions is shown greatly enlarged in figure 7. The first egg at the left (*A*) was taken from bamboo wood in which beetles were actively ovipositing. The shape and size of this egg and of those shown in figures 5 and 6 were typical of eggs found in bamboo. The other three eggs to the right (*B*), from 1 to 3 days old at time of photographing, were typical of those deposited loosely in oviposition vials.

The shape of the eggs was elongate oval and nearly straight to somewhat curved, depending on whether they were inserted in tubular vessels in bamboo wood or deposited loosely (figs. 5 to 7). In both cases, one end was more sharply rounded than the other and sometimes tapered a little for about one-fourth of the length of the egg. The color of newly deposited eggs was opalescent white, changing gradually with age to a waxy white. The surface at first was shiny and without apparent markings but later became dull and sometimes slightly granular to wrinkled a day or two before hatching.

Eggs from both locations were measured under the microscope. Those found in bamboo wood were at about the middle of their incubation period, but those found in excrement from corn had been deposited the day before. The average length of the eggs from both locations was 0.81 mm. However, the broad and narrow ends of the eggs deposited in bamboo wood averaged 0.22 mm. and 0.18 mm. in diameter, respectively; these extremities of the eggs deposited loosely were somewhat smaller (*10, p. 76*).

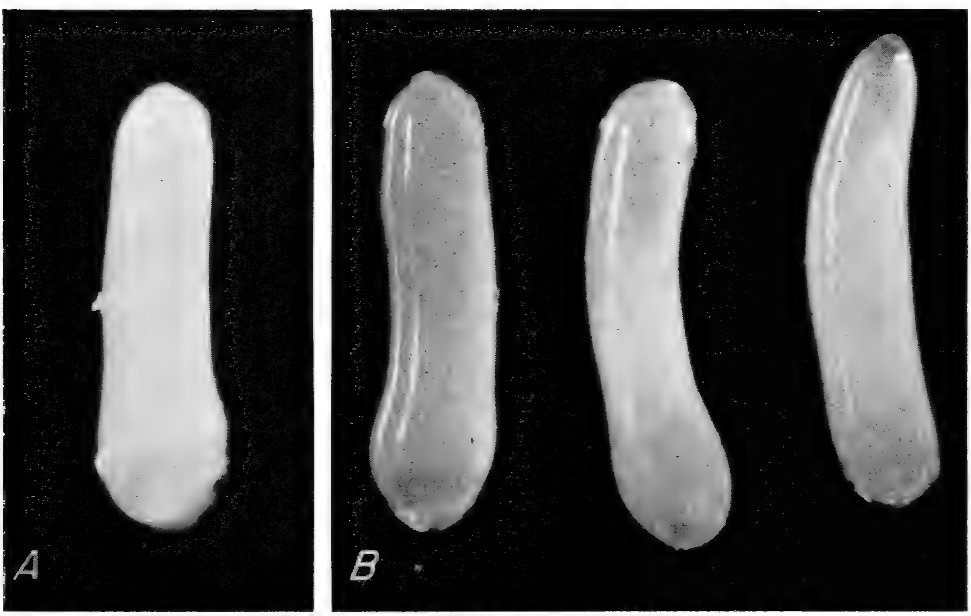

FIGURE 7.—Eggs of *Dinoderus minutus* of typical shapes and sizes: *A*, Egg taken from vessel in bamboo wood, × 65; *B*, three eggs found deposited loosely in excrement from dry sweet corn seed used as food for the beetles, × 70.

Eggs kept in tightly stoppered vials decreased in size as incubation progressed. Four eggs when newly deposited or in very early stages of incubation, averaged 0.81 mm. in length and 0.18 mm. in median diameter; when measured 24 hours later, they were found to have shrunk approximately 3 percent in length and 2 percent in diameter. Another egg on the day of deposition measured 0.91 mm. in length by 0.16 mm. in diameter; 5 days later, just prior to hatching, it measured 0.85 by 0.15 mm., a total shrinkage in both dimensions of well over 6 percent. All these eggs hatched into normal larvae.

Incubation records were secured from 144 eggs deposited between May 13 and June 28 and from 45 eggs deposited between July 1 and August 16.[4] These eggs were caged singly without added moisture in 2-dram homeo vials fitted with cork stoppers, and the vials were held in the laboratory where temperatures were estimated to approximate those recorded outdoors, as shown in table 1. The incubation periods for both lots are given in table 2.

TABLE 1.—*Mean weather-shelter temperatures at the Federal Experiment Station in Mayaquez, P. R., May to October 1940*

Month	Mean		Monthly mean
	Maximum	Minimum	
	°F.	*°F.*	*°F.*
May	88. 6	68. 9	78. 8
June	88. 9	69. 1	79. 0
July	90. 0	69. 5	79. 8
August	89. 7	69. 0	79. 4
September	90. 5	69. 6	80. 1
October	90. 0	70. 6	80. 3

TABLE 2.—*Incubation period of eggs of Dinoderus minutus deposited May to August 1940*

Period	Deposited May 13 to June 28		Deposited July 1 to Aug. 16		Total time
	Eggs	Total time	Eggs	Total time	
Days	*Number*	*Days*	*Number*	*Days*	*Days*
3	5	15			15
4	13	52	3	12	64
5	61	305	31	155	460
6	57	342	11	66	408
7	8	56			56
Total	144	770	45	233	1, 003
Average		5. 4		5. 2	5. 3

[4] For the sake of completeness these records include data previously reported (*10, p. 77*).

It will be noted in table 2 that the eggs deposited in May and June took from 3 to 7 days to hatch and averaged 5.4 days, while those deposited in July and August under somewhat warmer conditions hatched in from 4 to 6 days after deposition or an average of 5.2 days. For the total of 189 eggs under observation the average incubation period was 5.3 days.

Larva

In hatching under the conditions described above, the larva first broke through the larger end of the egg with the tip of its abdomen (fig. 8). This part of the body is armed with three short, dorsally

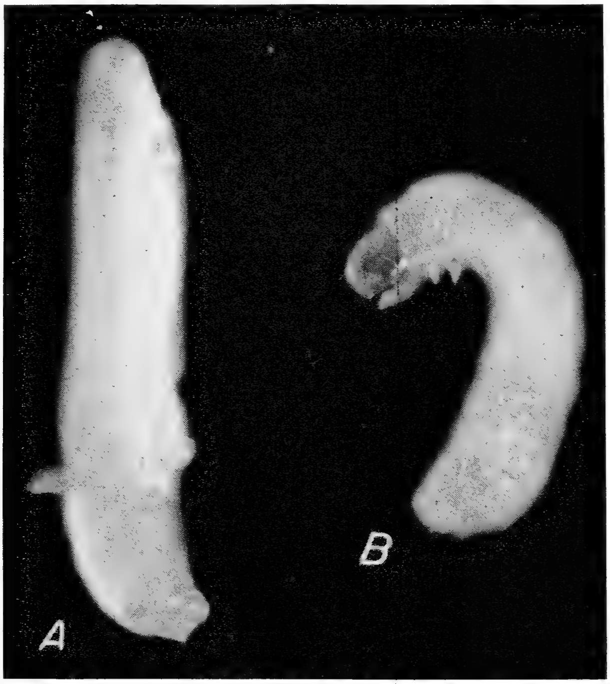

FIGURE 8.—Hatching and newly hatched larvae of *Dinoderus minutus: A*, Larva in the act of hatching, with tip of abdomen protruding through break in large end of eggshell; *B*, A new newly hatched larva, or first instar. Note hatching spines on last two segments of the abdomen of both larvae. × 70.

located spines, one broadly blunt in the middle of the last segment and one somewhat more acute on each side of the middle of the next-to-last segment. Assistance in rupturing the eggshell was doubtless rendered also by two short, tenacious prolegs on the last segment. Sometimes the shell was cut almost completely around so that the end remained fastened at one point like a lid. The larva then gradually backed out of the shell, or broke through at several points along the side while partly moving in and out through the first opening in the end; it was usually free from the shell in less than 24 hours after the first rupture.

Newly hatched larvae were slightly curved toward the head end, and this region was usually a little larger than the rest of the body. Measurements indicated a width of from 0.20 to 0.25 mm. and a length a little greater than the egg itself, or from 0.90 to 1.00 mm. The general color of the body was pale creamy white, and the surface was dull. The back and sides were sparsely clothed with slender white hairs about one-half as long as the width of the body.

Efforts to rear the larvae in kernels of corn or the powdery excrement from bamboo wood were unsuccessful. The powdery material from adult feeding and boring in corn gave better results, but the number reared was too small for practical use. Newly hatched larvae failed to enter bamboo wood of their own accord, even when placed on a roughened surface, some leverage apparently being needed to force their mandibles into the wood. No doubt, for this reason also they could not be reared in thin strips of bamboo held for observation between glass microscope slides. However, when placed head first into a small hole made in soft bamboo wood with a pin or dissecting needle held at an angle, they immediately began biting into the surrounding tissue and within several hours disappeared inside beneath a small pile of powder. In the few cases where necessary, entrance was facilitated by holding the blunt end of a needle or other object for a few seconds against the caudal end of the larva until the larva could bite into the wood and brace itself sufficiently against the sides of the hole to begin its burrow.

For developmental studies, newly hatched larvae were thus placed in separate ¼-inch radial sections about ¾ inch long taken from the middle internodes of young culms of *Bambusa vulgaris*. The infested sections were then caged in individual 2-dram homeo vials closed with corks or cotton and held upright in the laboratory where temperature conditions were about as shown in table 1. Progress of feeding and development was observed at approximately weekly intervals by chipping into the sections with a small, sharp knife, care being taken to make only shallow cuts and to split open the wood only sufficiently to observe the condition of the larva. The chipped wood was then gently sprung back into place with little disturbance of the larva. Mining by the larvae was slow at first, but as they grew older they began to feed voraciously. In single internodes infested for about 3 months, gnawing by both larvae and emerging adults has sometimes been so vigorous as to be plainly audible at a distance of 12 inches. Chapman [5] reported that in a heavily infested shipment of 48 tons of culms of *B. vulgaris* received at Philadelphia from Cuba he could hear gnawing by this insect at a distance of 3 feet.

Although it was not possible by the foregoing method to determine the length of each stadium, two molts were noted and evidence of two more were found in the frass left by larvae reared as above to the adult state and from dissections of first-stage larvae. Using measurements of the mandibles and Dyar's (*4*) method of calculating the number of instars of lepidopterous larvae, as described by Comstock (*3, p. 173*), it was estimated that the larva of *Dinoderus minutus* molts four times in developing from egg to pupa. The average length of the ventral (straightest) edge of the mandibles of two larvae was found to be as follows in the various instars—0.063, 0.113, 0.184, and 0.302 mm. Application of the ratio of the last two measurements, 0.61, as a factor gave mandible lengths in the first and second instars that corresponded closely with the actual.

Larvae in the last three stages of development were cream to dirty white in color, and, as will be seen in figure 9, were of the scarabaeiform

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[5] Personal communication from W. W. Chapman, Bureau of Entomology and Plant Quarantine.

FIGURE 9.—Developing larvae and a pupa of *Dinoderus minutus*. From left to right: Second, third, and fourth instars of the larva, respectively, and newly formed pupa with last larval skin clinging to tip of abdomen. × 9.8.

type, that is, had the general appearance of small "white grubs." The body was curved longitudinally, about half again as thick through the thoracic, or leg-brearing, region as elsewhere, and sparsely covered on the rounded back and sides with short, very pale reddish-brown setae or hairs. Full-grown larvae had an over-all length of 3 to 3.5 mm. and an abdominal width of about 1 mm. The head, short and about 0.5 mm. wide, was deep amber in color, the heavily chitinized tips and edges of the mandibles shading to black.

The total length of the larval period was determined for 98 larvae hatching from the two groups of eggs recorded in table 2. A summarization of the development of these larvae is presented in table 3.

The two groups had quite distinct periods of development. Seventy-three larvae hatching May 16 to July 5 from eggs deposited 3 to 7 days earlier took from 21 to 61 days, or an average of 33.8 days, to pupate, while 25 hatching July 6 to August 20 from eggs deposited July 1 to August 16 by the same stock of adults pupated in 48 to 76 days, or an average of 63.5 days. The longer period of development of the latter group, which was reared under otherwise identical conditions, extended into the months of September and October when the weather was slightly warmer. Unlike the eggs from which they came, the larvae developed more slowly as the temperature rose. The average period of development of all 98 larvae was 41.4 days.

Pupa

Pupation takes place in a cell prepared by the larva at the end of its mine in the wood. This cell, tubular in shape with rounded ends, is approximately 4 mm. long by 2 mm. in diameter and without lining or inside covering of any kind. Here, after a brief resting period (prepupal stadium), usually less than 24 hours, the last larval skin is shed, and, after several days more, the resulting pupa transforms to the adult state. A typical pupation cell containing a pupa is shown in figure 10. The newly formed pupa (figs. 9 and 10) is of about the

TABLE 3.—*Length of the larval period of Dinoderus minutus, May to August 1940*

Period	Hatched May 16 to July 5 [1]		Hatched July 6 to Aug. 20 [2]		Total time
	Larvae	Total time	Larvae	Total time	
Days	*Number*	*Days*	*Number*	*Days*	*Days*
21	1	21			21
22	3	66			66
23	1	23			23
24	5	120			120
25	2	50			50
26	2	52			52
27	3	81			81
28	3	84			84
29	5	145			145
30	7	210			210
31	5	155			155
32	2	64			64
33	2	66			66
34	2	68			68
35	1	35			35
36	2	72			72
37	4	148			148
38	2	76			76
39	2	78			78
40	2	80			80
41	1	41			41
42	4	168			168
43	3	129			129
44	2	88			88
45	1	45			45
47	2	94			94
48	1	48	1	48	96
49	1	49			49
50	1	50			50
54			1	54	54
55			1	55	55
57			1	57	57
59			2	118	118
60			4	240	240
61	1	61	1	61	122
62			2	124	124
63			2	126	126
66			1	66	66
68			1	68	68
69			4	276	276
71			1	71	71
73			1	73	73
75			1	75	75
76			1	76	76
Total	73	2, 467	25	1, 588	4, 055
Average		33. 8		63. 5	41. 4

[1] From eggs deposited May 13 to June 28. (See table 2.)
[2] From eggs deposited July 1 to Aug. 16. (See table 2.)

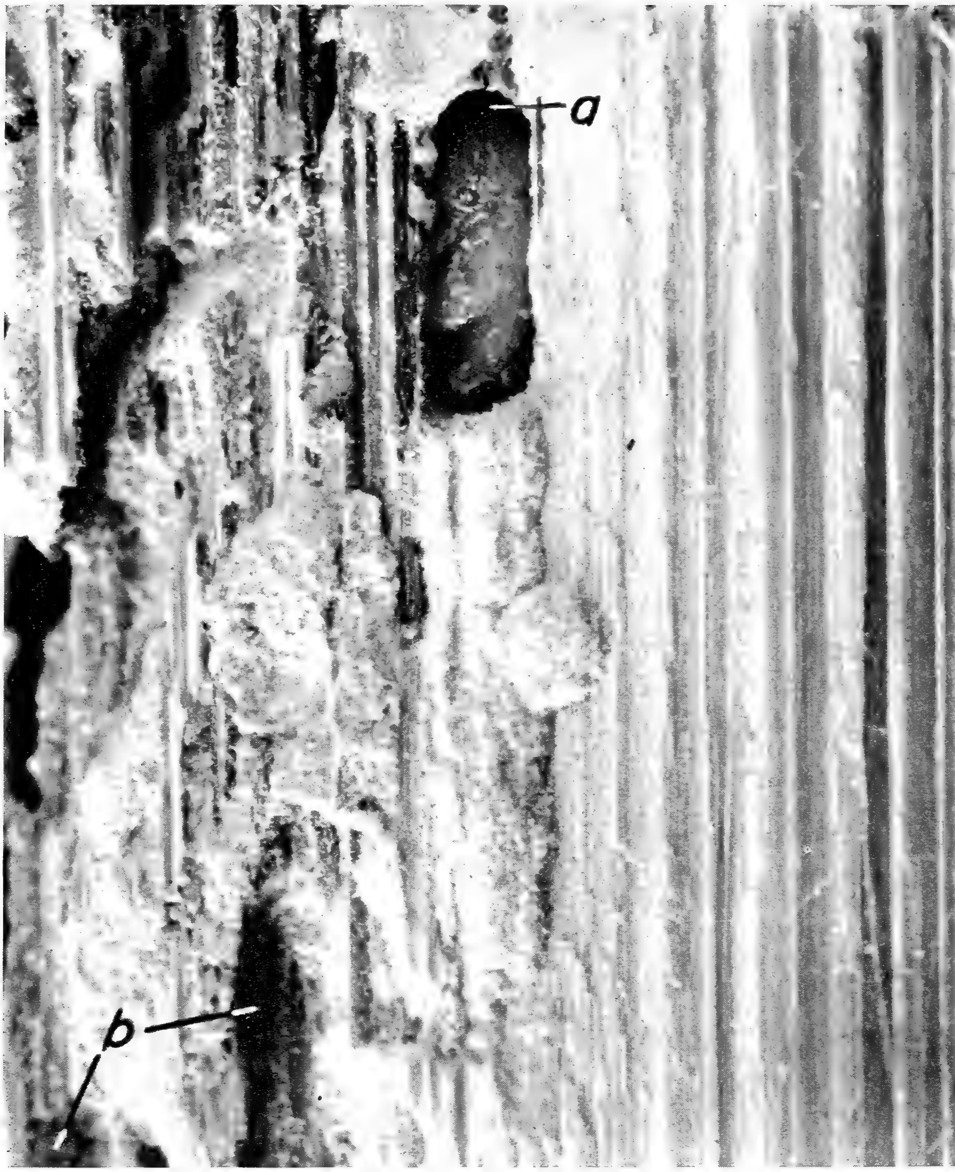

FIGURE 10.—Pupation cells of *Dinoderus minutus* at end of larval mines in soft, starchy wood of *Bambusa vulgaris*. Cell at top (*a*), still containing pupa, is typical of newly made cells; note mine behind pupa closely packed with powdered wood and excrement of larva. Emerged adults have already left cells partly shown at lower left (*b*). × 9.8.

same dimensions as the full-grown larva. Its color is glistening white at first, but gradually changes to an amber yellow by the end of the pupal period.

The length of the pupal period of 96 individuals observed between June and October is summarized in table 4. These individuals originated from the eggs and larvae recorded in tables 2 and 3.

In table 4 it will be noted that the pupal period was completed in from 3 to 5 days, the average time being 4.14 days. The 72 pupae

TABLE 4.—*Pupal period of Dinoderus minutus, June to October 1940*

Period	Pupating June 11 to Aug. 26 [1]		Pupating Sept. 5 to Oct. 8 [2]		Total time
	Pupae	Total time	Pupae	Total time	
Days	*Number*	*Days*	*Number*	*Days*	*Days*
3	7	21	2	6	27
4	47	188	18	72	260
5	18	90	4	20	110
Total	72	299	24	98	397
Average		4.15		4.08	4.14

[1] From larvae hatching May 16 to July 5. (See table 3.)
[2] From larvae hatching July 6 to Aug. 20. (See table 3.)

forming in June, July, and August averaged 4.15 days and the 24 pupae forming during September and October averaged 4.08 days.

Records were obtained of the continuous development of 93 individuals through the egg, larval, and pupal stages, i. e., from the time the eggs were deposited until the resulting adults emerged. This would correspond approximately to the time in which beetles may be expected to emerge and start a new infestation after the bamboo is first exposed to attack. These records are summarized in table 5.

To develop to the adult state, 69 individuals reared from eggs deposited in May and June took from 31 to 71 days, or an average of 43.5 days, while 24 individuals from eggs deposited during the next 2 months needed from 56 to 85 days, or an average of 72.9 days. The relatively slow development of the larvae in the latter group under the slightly increasing temperatures of August, September, and October (see table 1) more than counterbalanced their relatively short periods of incubation and pupation, and hence increased their over-all time of development from egg to adult. The average time for all 93 individuals was 51.1 days.

Adult

At the time of emergence the nearly cylindrical adult is creamy white in color, but as the chitin or outer covering of the body hardens, it changes to light amber and later to amber brown. Several weeks after emergence the adults vary in color from deep amber brown to black, and measure approximately 3 mm. long by 1 mm. wide. It will be noted in figure 11 that, in common with some other members of the same family, the head of *Dinoderus minutus* is covered by the prothorax, or first body segment. The front part of the top of the prothorax, or pronotum, is roughened by 4 or 5 transverse rows of 8 or 10 short, nearly triangular, up-turned spines each. These spines decrease in length and sharpness from the middle of the first row toward the back and sides. The remainder of the pronotum and the wing covers are coarsely pitted, and a short reddish brown bristle arises from the side of the bottom of each pit. All these bristles are of uni-

TABLE 5.—*Length of development of Dinoderus minutus from deposition of egg to emergence of adult, May to October 1940*

Period	Eggs deposited May 13 to June 28: Individuals	Eggs deposited May 13 to June 28: Total time to emergence of adults	Eggs deposited July 1 to Aug. 16: Individuals	Eggs deposited July 1 to Aug. 16: Total time to emergence of adults	Total time, egg to adult
Days	*Number*	*Days*	*Number*	*Days*	*Days*
31	2	62			62
32	2	64			64
33	3	99			99
34	3	102			102
35	1	35			35
36	4	144			144
37	2	74			74
38	4	152			152
39	4	156			156
40	5	200			200
41	5	205			205
42	2	84			84
43	1	43			43
44	2	88			88
45	3	135			135
46	2	92			92
47	3	141			141
48	2	96			96
49	2	98			98
50	1	50			50
51	1	51			51
52	4	208			208
53	4	212			212
54	1	54			54
56	3	168	1	56	224
59	1	59			59
60	1	60			60
63			1	63	63
65			1	65	65
68			3	204	204
69			3	207	207
70			1	70	70
71	1	71	1	71	142
72			2	144	144
73			1	73	73
75			1	75	75
77			2	154	154
78			2	156	156
79			1	79	79
81			1	81	81
82			1	82	82
84			1	84	84
85			1	85	85
Total	69	3, 003	24	1, 749	4, 752
Average		43. 5		72. 9	51. 1

form length. No dependable external characters could be found that would serve to distinguish the sexes.

As soon as the mandibles become hard enough, the beetle gnaws a hole to the nearest outside surface of the culm and thus liberates itself from the pupation cell. This exit hole is round or nearly so and of the same diameter as the oviposition tunnel, i. e., about 1.3 mm., or a little larger than the width of the adult itself (fig. 12). Of 94 reared adults 52 were observed to remain in their pupation cell for 2 days after emergence before making an exit hole, 38 remained for 3 days, and 4 for 4 days, the average being 2.5 days.

FIGURE 11.—Adults of *Dinoderus minutus*. From left to right: Dorsal, lateral, ventral, and lateroventral views. × 9.8.

The adults seem to be crepuscular in habit, that is, to be active during twilight or under conditions of low light intensity. It was frequently observed that the beetles began about midafternoon to leave their tunnels and to move toward the source of light. For a period of several days late in January, they were usually most active, with many taking flight, between 3 and 4 o'clock when the light was fading from 130 to about 4 foot-candles. The bettles were comparatively sluggish at 8 o'clock in the morning under about 15 foot-candles, but moved away from the light during the next half hour while it was increasing to 25 foot-candles. They also sought shade when placed in full sunlight during the middle of the day. Morning temperatures approximated 77° F. and those in the late afternoon 84°. While changes in temperature may have had some influence, it was evident that light intensity was a more critical factor governing the movements of the adults.

Mating was seen on one occasion while the female was starting to make her oviposition tunnel in bamboo wood. She had not burrowed deeper than about 0.5 mm. and was still easily accessible to the male. Although there was only this single observation, mating at this time could easily be of common occurrence, as well as elsewhere before or after entering the wood. More than one mating may take place, but frequent mating was found not to be necessary to continued production of fertile eggs. Without mating, eggs were deposited but none hatched.

Information on egg-laying activities that may be indicative of what takes place under natural conditions was secured from part of

FIGURE 12.—Exit holes made by adults of *Dinoderus minutus* on leaving a piece of 1-year-old culm of *Bambusa vulgaris*. Note large round holes, about 1.3 mm. in diameter, made directly through rind. The small, irregularly shaped holes were made by larvae mining close to surface. × 1.0.

the laboratory breeding stock used in the foregoing life-history studies. Thirteen adults recently emerged from bamboo of known date of infestation were confined with corn in one cage. Oviposition began 4 days after collection, and 93 eggs were deposited by the end of the next 19 days. The beetles were then caged separately, also with corn, and thereafter until the last insect died, 674 more eggs were laid by 7 of the beetles. These 7 beetles, which were assumed to be the only females present, deposited eggs over individual periods varying from 1 to 70 days and averaging 40.7 days. The greatest number of eggs deposited by a single female in 1 day was 11. Individual totals of up to 206 eggs were deposited by the 7 females during this latter period, or a possible maximum of at least 219 eggs and a general average of 109.6 eggs each from date of collection. Judging from composite samples of each day's deposition, all eggs from the first to last were fertile. Length of life after the last egg was deposited varied from 1 to 19 days, with an average of 8.6 days. Total length of life from date of collection ranged among the 7 females from 28 to 115 days, or an average of 78.6 days. The remaining 6 beetles did not lay eggs and were, therefore, assumed to be males; among these assumed males total length of life ranged from 74 to 154 days, and averaged 127.3 days.

Inasmuch as the above beetles were field-collected and therefore of unknown date of emergence, the foregoing figures are conservative. Reared, unmated beetles caged singly with corn were observed to begin depositing eggs in from 17 to 180 days after emergence (average 95.3 days) and to live longer than 186 days. Also, mass rearing indicated a somewhat greater reproductive capacity than that given above. Fifty field-collected beetles placed in a 6- by 9-inch battery jar filled with pieces of bamboo produced 2,985 beetles in 2½ months. Assuming that half, or 25, of the original lot were females, this would indicate an average deposition of 119.4 eggs each.

No distinct generations have been discernible throughout the year at Mayaguez, the number of individuals in any one stage of development present at any one time or season seemingly being entirely dependent on the availability of suitable material for oviposition and food for the larvae. Whenever a quantity of susceptible bamboo has been harvested and exposed to attack, larvae have been found in the wood within about a month or 6 weeks, and the following month adults have begun to emerge. Their peak of emergence is reached in about 3 months after the wood is exposed to attack. If a supply of infestive material is always at hand, it is possible for this insect to develop in Puerto Rico through approximately two to four overlapping cycles from egg stage to egg stage in 1 year. Advantage has been taken of this habit of continuous development to maintain a constant supply of stages for observation or experimental use. Each month a culm of the common bamboo in its first year of growth is harvested, cut into convenient lengths, say of one internode each, and placed in an open shed where it can become infested naturally. Some of the rind is cut off each piece to facilitate entrance of the beetles. Whenever *Dinoderus* material is needed, pieces of the proper exposure, depending on the stage or stages desired, are removed and the insects collected therefrom.

From the foregoing life history studies the length of the various stages in the life cycle of *Dinoderus minutus* may be summarized as in table 6.

TABLE 6.—*Summary of length of stages in the life cycle of Dinoderus minutus, May to December 1940*

Stage	Individuals observed	Duration		
		Minimum	Maximum	Average
	Number	*Days*	*Days*	*Days*
Egg	189	3	7	5. 3
Larva	98	21	76	41. 4
Pupa	96	3	5	4. 1
Egg to emergence of adult	93	31	85	51. 1
Adult				
In pupation cell [1]	94	2	4	2. 5
Life before oviposition	[2] 7	[3] 4		
Life before oviposition	[4] 23	17	180	95. 3
Oviposition	[2] 7	[5] 1	[5] 70	[5] 40. 7
Life after oviposition	[2] 7	1	19	8. 6
Total life, male	[2] 6	[3] 74	[3] 154	[3] 127. 3
Total life, female	[2] 7	[3] 28	[3] 115	[3] 78. 6
Total life, undifferentiated	[4] 57	29	[6] 186+	[6] 109. 8+
Egg to first oviposition	[4] 22	89	212	145. 3

[1] From emergence to making of exit hole.
[2] Collected from bamboo as recently emerged beetles.
[3] From date of collection from bamboo.
[4] Reared and unmated beetles.
[5] Beginning 23 days after collection from bamboo.
[6] Some adults were still living when observations were discontinued.

It will be noted in the last line of table 6 that 22 reared and unmated females began to deposit eggs to start a new life cycle in from 89 to 212 days after having themselves been deposited as eggs. The average cycle of these individuals from egg stage to egg stage was 145.3 days.

NATURAL ENEMIES

Few natural enemies attack the bamboo powder-post beetle in Puerto Rico, and none of them has thus far been observed to exert any appreciable control.

Doryctes jarvus Muesbeck (*8, pp. 150–152*), a braconid parasite of the larva discovered early in this work (*10, p. 78*), has usually been found in places where infested bamboo is stored. According to Muesebeck (*8, p. 152*), this species also occurs in the Canal Zone, Cuba, India, Java, and Australia. The adults, which are brown slender wasplike insects 2 to 2.5 mm. long (fig. 13), have been seen emerging from and entering holes made by *Dinoderus minutus* in culms that had been harvested for as short a time as 2 months. Adults of this species[6] have also been taken emerging from holes made by the larvae and adults of the lyctid beetle, *Minthea rugicollis* (Walker),[7] in dried roots of *Derris elliptica* (Roxb.) Benth., vars. Changi No. 3, St. Croix, and Sarawak Creeping.

[6] Determined by C. F. W. Muesebeck, Bureau of Entomology and Plant Quarantine.
[7] Determined by S. W. Fisher, Bureau of Entomology and Plant Quarantine.

FIGURE 13.—Adults of *Doryctes parvus*, a braconid parasite of the larva of *Dinoderus minutus*. From left to right: Lateral view of male and dorsal, ventral, and lateral views of female. × 9.8.

While the deposition of the egg has not actually been observed, developmental conditions suggest that it may be laid on or near the host larva, reached by means of the female's ovipositor from the comparatively clean oviposition or other tunnels made by the adult beetle. On hatching, the legless parasite larva, or grub, evidently does not enter the body of its host, but attaches itself to the outside, feeding on the body fluids through the body wall. Numerous *Doryctes* larvae in various stages of development from very small to full grown have been found attached singly in a subdorsal position to the thoracic or leg-bearing region of their hosts. Most of these host larvae were in their next-to-last instar. A parasite larva feeding on a last-instar larva of the powder-post beetle is shown in figure 14.

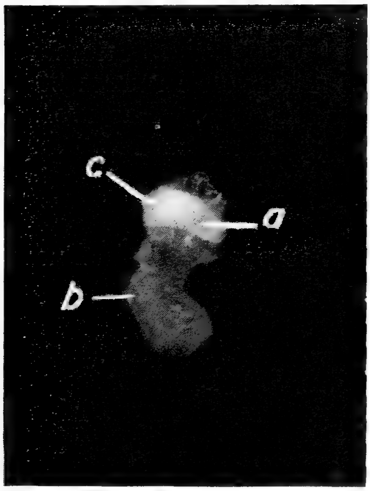

FIGURE 14. — Approximately half-grown larva of the braconid parasite, *Doryctes parvus* (*a*), feeding on a last stage larva of *Dinoderus minutus* (*b*). Note characteristic point of attachment of parasite larva to side of thoracic, or leg-bearing, region of host (*c*). × 9.8.

Pupation takes place in a white, closely spun cocoon made in the pupation cell of the host larva (fig. 15). If, as is sometimes the case, the host larva has mined through to the surface of the culm before the parasite has killed it, or has made its cell close enough to the surface so that only a thin piece of wood separates it from the outside, the emerging adult parasite can free itself (fig. 15, *a*). However, many adult parasites have been found dead in pupation cells so unfavorably located (fig. 15, *c*) that they were unable to escape. This may be one of the factors limiting the effectiveness of this parasite.

Adults of another small wasp, the pteromalid, *Proamotura aguila* Girault,[8] have occasionally been found emerging from bamboo infested with *Dinoderus*

[8] Determined by A. B. Gahan, Bureau of Entomology and Plant Quarantine.

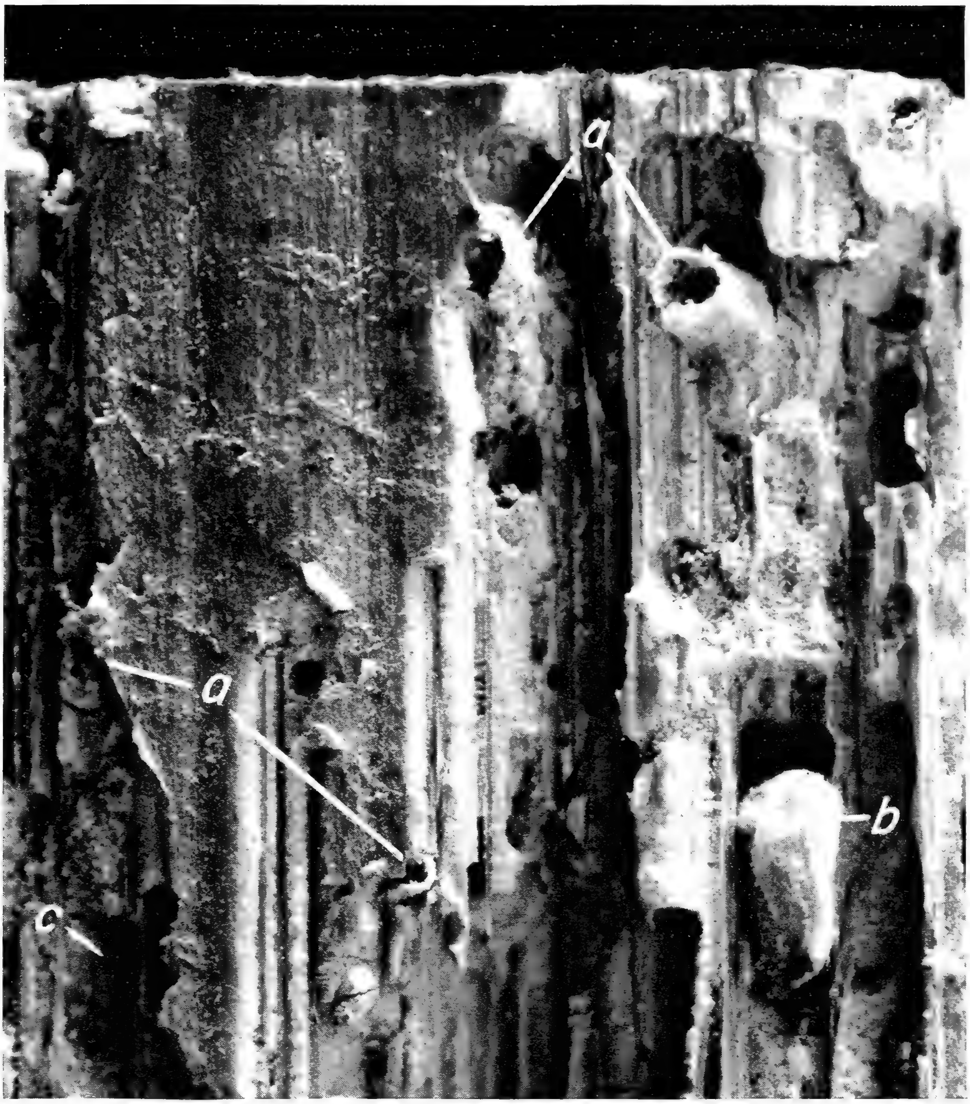

FIGURE 15.—Cocoons of *Doryctes parvus*, a braconid parasite of the larva of *Dinoderus minutus*, spun in pupation cells of host in bamboo. Part of the inside wall of the bamboo culm was cut away to expose four empty cocoons (*a*) and one from which the adult parasite had not yet emerged (*b*). Adult parasites were found emerged but dead in pupation cells located so deep in the wood that they could not escape (*c*). × 9.8.

minutus. According to Gahan (*6*), this parasite was described in 1920 from specimens reared from bettle-infested twigs of *Mallotus philippinensis* collected at Brisbane, Australia. It is apparently widely distributed, having also been recorded from the Fiji Islands, the Philippine Islands, Mexico, and Cuba (*6*). The head and thorax of the adult are brown and the abdomen is black. As will be noted in figure 16, the adults are about 3 mm. long, slightly larger than *Doryctes*, and the antennae are club-shaped instead of filiform. In living specimens the antennae are held nearly horizontal and extend forward. This species is internally parasitic on the pupae

FIGURE 16.—Adults of *Proamotura aquila*, a pteromalid parasite of the pupa of *Dinoderus minutus*. From left to right: Laterodorsal, lateral, dorsal, and ventral views. × 9.8.

of the powder-post beetle, and the small, naked, amber-colored pupae are usually found in the borer tunnels near the remains of this stage of the beetle. Some parasite pupae and their host remains are illustrated in figure 17. The number of both adults and pupae of *Proamotura* encountered at any one time has been so much smaller than those of *Doryctes* that there is considerable doubt as to the effectiveness of this insect as a parasite of the beetle.

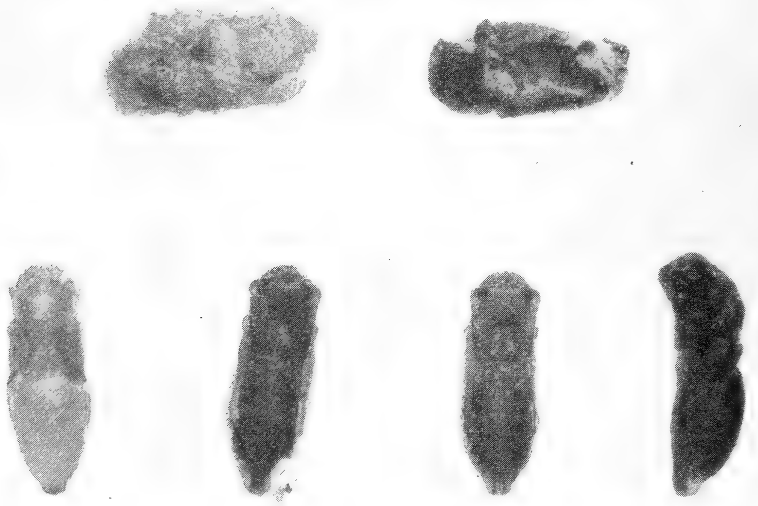

FIGURE 17.—Pupae of *Proamotura aquila*, a pteromalid parasite of the pupa of *Dinoderus minutus*. Above: Host pupae showing large parasite emergence hole in back of abdomen. Below, from left to right: Dorsal, two ventral, and lateroventral views of parasite pupae, photographed 2 days before emergence of adults. × 9.8.

Other closely related parasites have been recorded as reared from *Dinoderus minutus* in other parts of the world. Gahan (*5, pp. 84–85, 100–102*) has described the braconid, *Spathius dinoderi*, and the pteromalid, *Cerocephala* (*Parasciatheras*) *dinoderi*, from material reared in the Philippine Islands. Bruner et al. (*1, p. 18*) list "*Cerocephala* (*Parasciatheras*) sp." as a parasite of the larvae in Cuba. Even though these parasites should prove to be no more active than the ones already here, their introduction into Puerto Rico may be of some assistance in the natural control of this troublesome insect.

Peregrinator biannulipes Montr., a reduviid bug, occurs as a predator of the adult of *Dinoderus minutus* under much the same conditions as the foregoing parasites. Having a body length between 6 and 7 mm. and a width of about 2.5 mm., the adult is predominantly light brown in color, with the exception of the membrane of the forewings, which is black. All other parts are densely clothed with short hairs which, by holding particles of powdered wood thrown out by the beetle, give the bug a dusty appearance of the same color as its surroundings (fig. 18). The nymphs are also light brown in color and covered with hairs. Being without wings or with wings only partly developed, the nymphs accumulate so much wood dust over their entire

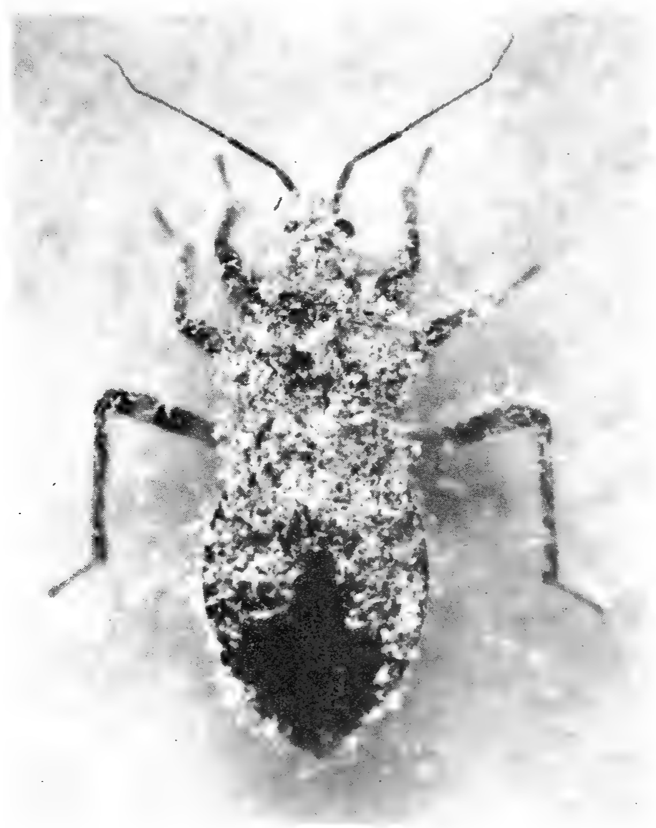

FIGURE 18.—Adult of *Peregrinator biannulipes*, a reduviid predator of the adult of *Dinoderus minutus*. Note characteristic accumulation of powdered wood from burrows of host, held by short hairs over body and legs. The bands noticeable about the middle and apex of the femora are dark brown in color. × 9.8.

bodies as to be unrecognizable until disturbed, when they then look like small mounds of moving debris (fig. 19). These predators have never been found on the inside of infested wood, but both adults and nymphs have been observed to prey on the adult beetles as they emerge from their tunnels (*9*). This habit confines their usefulness largely to a reduction of beetle population at a time when much damage has already been done.

In connection with the large-scale rearing of the beetle for experimental use previously mentioned, opportunity was afforded to observe the effectiveness of this predator and *Doryctes* under conditions comparable to those of undisturbed common storage. After several months' supply of infested wood had accumulated, both the predator

FIGURE 19.—Nymphs of *Peregrinator biannulipes*, a reduviid predator of the adult of *Dinoderus minutus*. Like the adults, but without wings or with wings only partly developed, the nymphs accumulate so much wood dust over their entire bodies as to be indistinguishable until disturbed, when they then look like small mounds of moving debris. × 9.8.

and the parasite multiplied to such an extent that they could easily be seen on or among the infested pieces of bamboo or the usual dust therefrom. However, no retarding was noticeable in infestation of the susceptible new wood supplied monthly, and, while there may have been some reduction in powder-post beetle population at first, the reduction never perceptibly hampered the continuous production of a generous supply of any stage of the beetle desired.

Peregrinator biannulipes is mentioned by Miller (*7, pp. 18–20; pl. II, fig. 8*) as a predator of the larva *Xylopsocus capucinus* F., a bostrichid infesting dried derris root in Malaya. Miller also states that it has "been recorded in Ceylon, Burma, the South Sea Islands, Bourbon, Central America, and the Antilles, besides the Malay Archipelago."

Tenebroides sp., probably *T. punctulatus* Chev.,[9] a black beetle about 8 mm. long, was encountered only once and this was in a cage containing infested bamboo. No evidence of feeding on the bamboo by the

[9] Determined by S. W. Fisher, Bureau of Entomology and Plant Quarantine.

two adults present could be detected. When placed in another cage containing uninfested bamboo and a fresh supply of beetles they refused the wood but readily attacked and dismembered all the beetles they could reach. *T. punctulatus* has been know to be present in Puerto Rico for a long time (*13, p. 218*), and it belongs to a family, the Ostomidae, which includes some widely distributed forms that feed on grain as well as insects. The species found is probably only casually predaceous on the bamboo powder-post beetle.

Immature mites of the families Parasitidae and Tyroglyphidae,[10] have been seen on several occasions attacking eggs and larvae of *Dinoderus minutus* which were being reared in loosely stoppered vials. Eggs were the more frequently attacked and then only to the extent of 1 or 2 percent of the stock handled. Under natural conditions, mites have never been observed to molest any stage of the beetle.

SUMMARY

The bamboo powder-pest beetle (*Dinoderus minutus* (F.)) is a small wood-boring bostrichid that is widely distributed in the tropical regions of the world. It frequently becomes so abundant in Puerto Rico as to destroy or seriously damage great quantities of harvested bamboo and other dry vegetable products. The Spanish common name, "escarabajo del bambú seco," serves to prevent confusion with the powder-post or dry-wood termites, *Kalotermes* (*Cryptotermes*) spp., that are locally known as "polilla" and have a somewhat similar habit of casting out droppings from their burrows.

Infestation is begun by the adults. In bamboo, they gain entrance at a break in the rind or at the leaf-sheath scar about the nodes and buds, frequently within 24 hours after the harvested culms are assembled for drying or storage. Dead or dying culms left in the clumps in the field have rarely been seen attacked, never those that are growing.

For the purpose of oviposition, the adults extend their tunnels at right angles to the grain of the wood in the soft, pithy tissue on the inside of the culm. In the tubular vessels of the fibrovascular bundles thus cut they deposit elongate-oval eggs which are about 0.81 mm. long and 0.20 mm. in diameter. The more starch in the surrounding tissue the heavier is the resulting infestation.

Dry kernels of corn provided a suitable oviposition medium for use in securing eggs for life history studies. These eggs hatched in from 3 to 7 days.

Larvae reared in small pieces of bamboo had a feeding period of 41 days. They molted four times and extended their mines parallel to the grain in the soft, starch-bearing tissue of the wood.

Pupation takes place in a small, unlined cell prepared by the nearly full-grown larva at the end of its mine. The usual pupal period was 4 days.

The emerged adult spent about 3 days in its pupation cell before gnawing an exit hole to the outside. Development from deposition of the egg to emergence of the adult averaged 51 days. This approximate time in which beetles may be expected to emerge and start a

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[10] Determined by H. E. Swing, Bureau of Entomology and Plant Quarantine.

new infestation ranged from 31 to 85 days. The adults were attracted to the fading sunlight of midafternoon.

Mating was necessary to the deposition of fertile eggs. Without mating eggs were deposited but none hatched.

Some reared and unmated beetles were observed to live as long as 186 days, and a few started to lay eggs within 17 days after emergence. Field-collected, recently emerged beetles began in 4 days to deposit an average of 110 eggs each over an average period of 41 days; 11 eggs were the maximum number deposited by a single such female in 1 day.

No distinct generations have been discernible throughout the year at Mayaguez. The number of individuals in any one stage of development present at any one time or season appeared to be entirely dependent on the availability of suitable material for oviposition and for food for the larvae.

The average life cycle of 22 reared and unmated females from egg stage to egg stage was 145 days; some completed this cycle in a minimum of 89 days, others in a maximum of 212 days.

One braconid parasite of the larvae, one pteromalid parasite of the pupae, and one reduviid predator of the adults, all reported present in other parts of the world, occurred where infested bamboo was allowed to accumulate, but none was observed to reduce the beetle population before considerable damage had been done.

An ostomid beetle and immature mites of two families were only casually predaceous on the adults, eggs, and larvae.

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